



Cottage Scale Eco-Friendly Process For High Quality Biochar Production

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Abstract

Biochar is generally produced through pyrolyzing of organic feedstocks in limited oxygen atmosphere. Though high demand for biochar, due to the hazardous smoke generation, cottage scale biochar production is still not popularized. Cottage scale operators produce biochar through primitive traditional techniques, resulted high smoke emission and yields less quality product. Coconut shell charcoal is the major biochar variety in Sri Lanka, mostly used as a raw material for activated charcoal. Large-scale producers use additional firewood kiln to secondary burn the generated smoke from biochar production. Retort technique is one of the suitable methods, however it is not attracted by cottage scale producers due to its capital intensiveness. This study aims to introduce cottage scale LP-Gas fired kiln to produce high quality biochar material with less moisture content, compared with the other traditional methods. The proximity analysis of resulted coconut shell charcoal had high fixed carbon (86.43 %) and gross calorific value (7654.7 kcal/kg). The novel process emits less smoke than other traditional methods, can be used for filling the gaps in ecofriendly charcoal production. This approach has the ability to produce high quality biochar from semi-dried materials and feedstock with different densities such as twigs, leaves and flowers. The resulted low-density biochar can lead to novel applications. Introduction of this process is expected to gain social and societal benefits.

Keywords: Biochar, domestic-scale production, high-quality biochar, fixed carbon

1 Introduction

Biochar is the carbon rich valuable material and having myriads of applications starting from biofuel, soil enhancing material, environmental remediation agent and also used as an absorbent material. The general terminology of the biochar is known as charcoal made from the agricultural biomass, municipal wastes, sewage sludge and commonly prepared through firing at temperatures of 300–700 °C [1], [2]. Demand of various applications of the biochar depend on its high carbon content with stable structure, cation exchange capacity with high surface area [2]. Demand for the high-quality biochar is increasing and new applications are introduced with the advancement of the research findings. High quality biochar has high demand as raw material for activated charcoal production, carbon source for smelting in metal processing, and various novel applications are unveiling. The critical problem in the biochar production is the high smoke generation and limited

due to the stringent environment protection practices in Sri Lanka. Coconut shell charcoal is the common biochar industry in Sri Lanka and major demand for preparation of activated charcoal through superheated steam activation process. And also, Sri Lanka has reputation for high quality activated charcoal [3]. Therefore, the gap between high demand and less supply of the coconut shell charcoal in Sri Lanka can be overcome by the production at small and cottage scale. Emission of the charcoal production contain toxic gasses and chemicals such as carbon monoxide, tar and pyroligneous matter, therefore traditional charcoal processing is recognized as inefficient and environmental polluting activity [1]. However, high emission of the smoke is the limitation of the cottage scale charcoal production. The retort system is the one of advanced charcoal production technique, while most of retorts has high capital intensive and not attract the cottage scale.

This study mainly focused on the coconut shell charcoal production due to its established market potential and this process can be used for low density feedstocks also. Coconut shell biochar has the premier applications such as material for counter electrode of dye-sensitized solar cells and super capacity electrodes [3], [4], [5], [6], for pollutant removal [7], [8], effective bio fuel for general applications [9], fuel for melting of metals and metal-composite material preparation [10], [11]. Other than the coconut shell charcoal, biochar from different feedstocks used in soil improvement through moisture retention, nutrient enrichment and substrate for soil microbiota and detoxify the soil [12], [13], [14]. Sorption properties of various biochar materials were extensively studied and properties depend on the type of feedstock, pretreatments, and pyrolyzed temperature [15], [16]. Biochar and its composites were developed for catalytic activity [17], [18].

Though the biochar used for remediation of soil, toxic effluent purification and other ecofriendly applications, production of biochar has big impact to the environment due to emission of dust and smoke [1], [19]. Retort system is the advanced process to minimize emission of smoke and gas through secondary burning of gas effluent, prior to emit to the environment [20]. In 2009, yearly charcoal consumption of Kenya was estimated as 2.4 million tons and Zambia as 1 million tons and 10.7 billion m³ of air pollution was estimated annually in the region of Kenya and Zambia [20]. The retort kiln is ecofriendly with lesser emission than traditional processes and recognized as efficient method for biochar production due to re-combust the generated flue gas and utilize the energy for carbonizing of the feedstock, and also yield high-carbon content ($\geq 50\%$) at temperatures around 500 °C [21].

The aromatic and graphitic nature of the biochar with high processing temperature has important electrochemical charge transfer property and can be used for supercapacitors [22]. Six-order increment of conductivity of biochar resulted the carbon content changed from 86.8 to 93.7% by weight due to graphite nanocrystal formation (~ 3 nm) at 950 °C [23]. The increment of the pyrolyzing temperature had improvement of the specific surface area, pore volume, aromaticity of biochar and above the temperature of 700 °C, the graphite-like structures had formulated [24]. The aromatic cluster lateral size is the critical parameter and beyond that the biochar becomes rapidly expanded and more cluster lateral size has more absorption ability [24]. According to the above findings, pyrolytic temperature of the kiln has direct relationship of the properties of the biochar.

2 Methods

Production method

The domestic scale “kiln and tort system” was fabricated using the low-cost materials. The kiln consisted of the refractory cover, stove and the stand. The stand was prepared using cement-mortar bricks, refractory cover was prepared using clay-cement-sand mixture filled in between two thin (0.5 mm) GI cylinders and placed on the iron grill and stand. The refractory mixture contains cement: Sand: Clay as 1:3:2. The domestic scale LP gas stove with two-ring burner was the firing source. The tort is the cylindrical vessel prepared in Galvanized Iron (GI) material, for accommodating the biomass, and size of the tort with a lid was 20 cm in diameter and 50 cm in height. The lid was fastened after filling the loosely packed biomass in to the tort. The tort was inserted into the kiln in the upside-down manner. When firing the thin GI sheet was used to cover the top of the kiln to circulating the flue gas inside the kiln. It helped to increase the efficiency of firing and minimize the smoke emission. Depending on the type of biomass (from low density matter, tree leaves and flowers to medium density matter, coconut shells), the production time varies from 30 minutes to 2 hours. The large-scale operation (100 kg of coconut shell, wet basis) was run using the kiln prepared using industrial refractive bricks and thick stainless-steel sheets. The LP gas used to maintain un-interrupted uniform quality of flame, throughout the firing operation. Pressurized smoke and flue gas emitted through the tort was utilized as the secondary fuel of this operation. The advantage of this operation is the semi-dried and wet samples can be fired and without sacrificing the final quality of the biochar.

Testing methods

The Gross calorific value of coconut shell charcoal was determined by the ASTM D: 5865 standard and using the Gallenkamp bomb calorimeter. the proximate analysis was determined as per BS EN 1860-2. Each test was triplicated for better accuracy. The smoke generation was observed visually and recognized by its smell by experienced personnel and they claimed it is less smoke generation than common household cooking operation with firewood stove.

3 Results and Discussion

The coconut shell charcoal preparation has high demand in Sri Lanka for mainly for the raw material for the activated charcoal production and other industrial applications. The supply of the coconut shell charcoal is limited in Sri Lanka and major players of activated charcoal industry tend to import un-activated coconut shell charcoals. Current production process of the coconut shell charcoal is primitive in Sri Lanka and environmental pollution is the major concern. Therefore, this innovative approach was introduced. Physical properties of the coconut shell charcoal from this cottage scale process are given in Table 1.

The proximate analysis of the coconut shell was reported as 66.1% for volatile matter, 1.4% of Ash content and 24.8% of fixed carbon [25]. Comparing with the reported findings on proximate analysis of coconut shell with produced charcoal in this process, charcoal had decreased the volatile matter to 7.78% and increased the fixed carbon to 86.43%, due to reduce the volatile matter in the

Table 1: Proximate analysis and Gross calorific value of coconut shell charcoal

Parameter	Result (Mean $\pm$ Standard deviation)
Proximate analysis	
% Moisture content, wet basis	7.67 ± 0.1
% Ash content, dry basis	6.46 ± 1.0
% Volatile matter, dry basis	7.78 ± 0.2
% Fixed carbon, dry basis	86.43 ± 0.2
Gross calorific value, kcal/kg	7654.7 ± 299.7

thermochemical carbonization reactions. Ash content of resulted coconut shell charcoal resulted 6.46% compared with the reported value for coconut shells of 1.4% due to the condensation of minerals in pyrolysis process. Considering the high fixed carbon content, coconut shell charcoal can be used for various applications not only used as energy source.

The Gross calorific value of the coconut shell charcoal was resulted as 7654.7 kcal/kg with comparing the reported value of 4339.85 kcal/kg [25] and more energy can be derived from unit weight of coconut shell charcoal. Compared with the results obtained from the proximate analysis and Gross calorific value of the resulted coconut shell charcoal, this cottage scale biochar making process is competent to make the quality biochar material for various applications other than the application of the fuel. It was observed that, cross section of the coconut shell charcoal (when breaks) had graphite like colour and expected that some sites were tend to graphitization due to high temperature reactions.



Figure 1: Leaf biochar produced in this technique

This technique was used for carbonizing the both semi-dried and wet plant-based materials to make biochar. Also, low-density materials such as flowers, twigs and leaves, to make good quality charcoal material. The figure1 depicts the resulted biochar of “Ceylon Cinnamon” (*Cinnamomum zeylanicum*) leaves. The surface of leave-biochar had graphite like colour with a silver colour tint. It is observed that, a multi-colour tint on the surface of the biochar due to the thermochemical reaction of leached cations at high temperature (700–900 °C). However, this tint (yellowish golden to dark blue) was disappeared after several days due to re-absorption of cations with moisture re-gain of the biochar.

4 Conclusion

Development of the cottage scale biochar processing technology with the less capital intensive than the sophisticated retort system, with addressing the environmental concerns in the traditional charcoal making processes was successfully achieved. The prepared coconut shell charcoal was evaluated through the standard testing methods and ensure the quality of charcoal material. In this process wet feedstocks, and low-density plant-based materials (leaves, flowers and twigs) can be used for carbonization with high yield of good quality charcoal. Therefore, it is concluded that the domestic scale charcoal production novel technique can be used for the economic development of the rural livelihoods.

5 References

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